DOCUMENT RESUME

ED 223 247 IR 010 516

AUTHOR Brannstrom, Lauritz
TITLE Effects of Spatial Configuration on Visual Attention Processes. Umea Psychological Reports No. 154.
INSTITUTION Umea Univ. (Sweden).
SPONS AGENCY Swedish Council for Social Science Research, Stockholm.
PUB DATE 80
NOTE 20p.; For related documents, see IR 010 515-518.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cognitive Processes; Dimensional Preference; *Eye Movements; *Patterned Responses; Psychological Studies; Spatial Ability; Tachistoscopes; *Visual Perception; *Visual Stimuli
IDENTIFIERS Form Reproduction Task; Pattern Organization; *Scanning; Selective Attention; *Stimulus Characteristics

ABSTRACT

The significance of spatial factors on an initial segmentation and an active attentional phase was demonstrated by briefly exposing spatial configurations of elements, and then asking the subjects to reproduce the patterns or to search them for a target letter. The stimulus displays consisted of small o's forming different spatial configurations, varying in density and exposed by means of a two-channel tachistoscope. Judgmental classification of reproduced patterns revealed that the segmentation phase is affected by the form of the functional field of view, retinal position, spatial redundancy, and density. The pattern of the attended positions in the search phase reflected the impact of certain specific properties of the spatial configurations and the task requirements. The results lend support to the validity of the suggested differences in the modes of processing. Data tables and four references are included in this report. (Author)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED223247

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.

Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

EFFECTS OF SPATIAL CONFIGURATION ON VISUAL ATTENTION PROCESSES

by

Lauritz Brannstrom

UMEA PSYCHOLOGICAL REPORTS

No. 154 1980

Department of Psychology
University of Umea

IR010516

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Lauritz Brannstrom

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

EFFECTS OF SPATIAL CONFIGURATION ON VISUAL ATTENTION PROCESSES

Brännström, L. Effects of spatial configuration on visual attention processes. Umeå Psychological Reports, No. 154, 1980. - The significance of spatial factors on an initial segmentation and an active attentional phase was demonstrated by briefly exposing spatial configurations of elements and then asking the subjects to reproduce the patterns or to search them for a target letter. Judgmental classification of reproduced patterns revealed that the segmentation phase is affected by the form of the functional field of view, retinal position, spatial redundancy, and density. The pattern of the attended positions in the search phase reflected the impact of certain specific properties of the spatial configurations and the task requirements. The results lend support as to the validity of the suggested differences in the modes of processing.

Little is still known about the role of configurational aspects of visual stimuli on attentional processes (Estes, 1978) although the theoretical and practical relevance of such knowledge should be out of question. Spatial factors should, first, be critical for the segmentation into perceptual units with gestalt-like properties (figure/ground segregation and figural organisation; Haber & Hershenson, 1973), and second, affect the distribution of visual attention e.g. by reducing the number of applicable scanning strategies. The latter effect should also be contingent on the task requirements. Accordingly, the theoretical framework used here presupposes an initial, relatively passive or unconditional phase, where the sampling of information and the formation of perceptual units is restricted by certain basic properties of the visual system, like the form of the functional field of view. The effective stimulus variables are e.g. retinal position, contours, and density of elements. In the next processing phase, visual attention is jointly determined by the configurational aspects of the stimulus pattern and the task requirements. The purpose of the present experiment was to compare the effects of spatial configuration on both the immediate perception and the later search phase.

The initial phase was studied by asking the subject to reproduce only the gross features of his immediate perception when patterns of stimulus elements were briefly exposed. Spatial configurations containing elements close to the fixation point should be easy to detect as compared to configurations free from central elements. The functional field of view is probably ellipse-shaped with its main axis horisontally oriented (cf. the equal-accuracy contours found in the experiment by Schaller & Dziadosz, 1975). Thus, another prediction is that horisontally and vertically oriented configurations will differ in their detectability. For the same reason subjects should be more or less prone to confuse the stimulus patterns. Further, increased density of elements should facilitate the segmentation phase by making the configurational properties of the stimulus pattern more conspicuous.

In the search phase the subject's task was to find one target element in the stimulus pattern. The exposure was sufficiently long to permit accurate identification of the elements of the pattern. The scanning strategy used by the subject should be closely tied to the configurational aspects of the pattern. For spatially systematical configurations, the subject may be expected to attend to elements preferably in the upper-left and the lower right quadrants of the stimulus field (Brännström, 1980). However, the diagonal scanning strategy should be modified depending on the orientation of the grouping of elements within the systematic stimulus patterns. For the random configurations, the scanning should depend mainly on the clarity of elements, i.e. the retinal position.

An additional, compound task was used to test the influence of the reproduction task on the scanning strategies. The subject both reproduced the gross features of the stimulus pattern (main task) and indicated the target position (secondary task).

Method

Stimulus material

The stimulus displays consisted of small o:s forming different spatial configurations varying in density. The stimulus patterns are displayed in Figure 1.

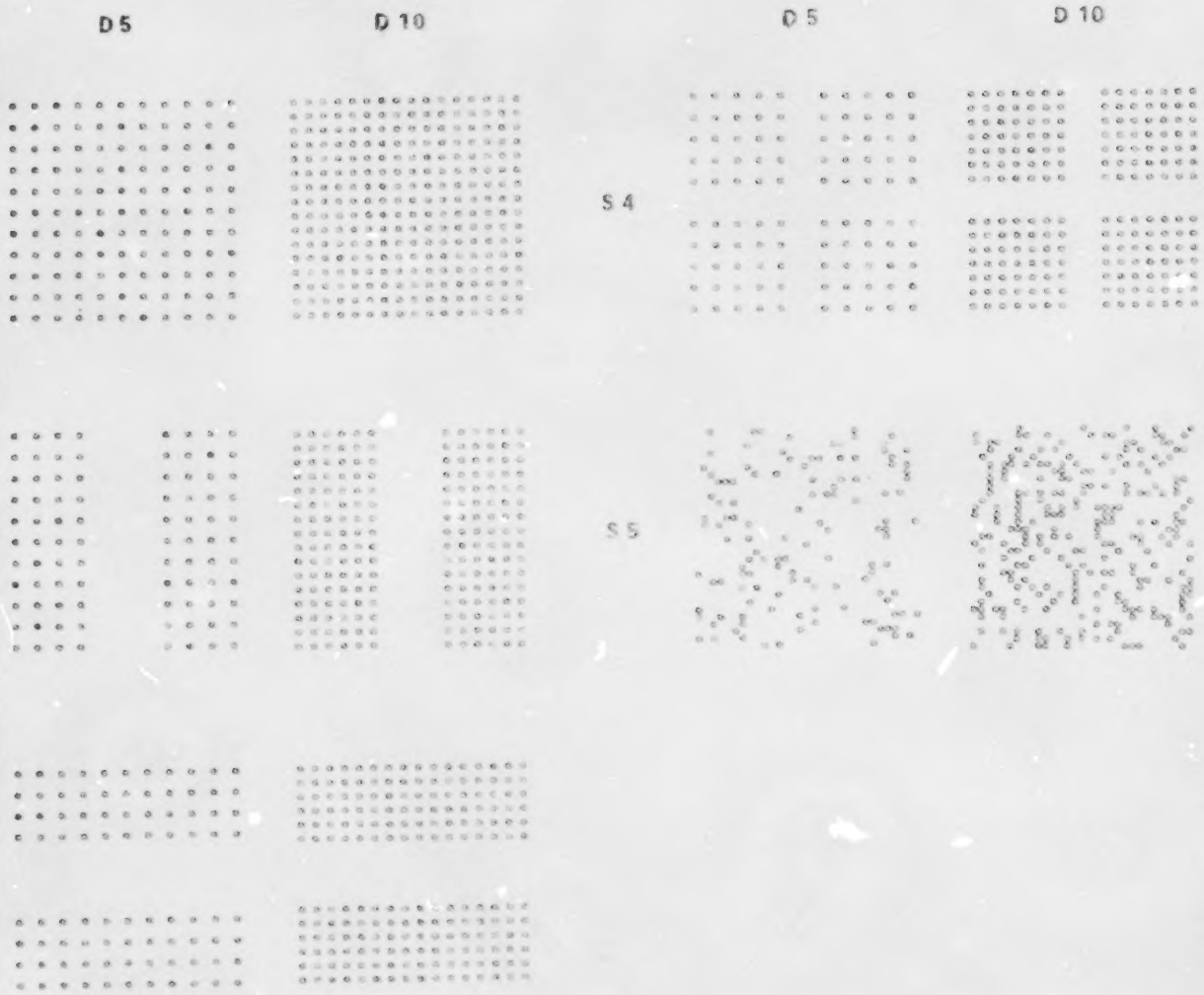

Figure 1. The stimulus patterns.

Thus, the stimulus pattern S1 was homogenous and systematic (redundant). S2 and S3 were systematic configurations with the elements forming two groupings separated by vertical and horisontal inner empty fields, respectively. S4 was also systematic, but contained four groupings into quadrants. Finally, S5 consisted of randomly located elements.

The total display area with elements was 24.60 square degrees (4.96° x4.96°) with a viewing distance of .75 m. There were approximately 5 elements/square degree for low density (D=5) and, 10 elements/square degree for high density (D=10). The minimum distance between the center positions for two adjacent elements was $.49^{\circ}$ for D=5 and $.32^{\circ}$ for D=10. The number of elements within the stimulus patterns S1-S5 were for D=5: 121, 88, 88, 100 and 121, respectively. For D=10 the corresponding numbers were 256, 192, 192, 196 and 256, respectively.

For each density three stimulus displays were generated for S1-S4 and six for S5. Thus, the total number of stimulus displays was 36. The higher proportion of S5-displays (one third of all stimulus displays) was used in order to increase the stimulus uncertainty and thus force the subject to base the reproductions on his immediate perception of the gross features of the stimulus patterns rather than on inferences about them. Twenty-four of the stimulus displays contained one target, the letter c. It could occur in any of the center areas of the four quadrants formed by the main horisontal and vertical axis through the midpoint of the stimulus pattern. Across densities there was one target per quadrant for S1-S4, while there were two targets for S5. Thus, the target position was counterbalanced for each stimulus pattern. The stimulus elements and the target were generated on an IBM typewriter with ARTISAN typehead; they were printed in black on a white background.

Procedure

In an experimental session the subject completed four tasks in a fixed order. The task requirements varied for the immediate perceptual phase and the search phase. In the first and the second task the subject was

instructed to reproduce his immediate perception of the stimulus pattern exposed. The subject was to encircle sets of perceived elements on a homogenous response matrix consisting of 256 positions. Task 2 differed from task 1 in that the subject was free to reproduce either sets of perceived elements or those not perceived.

The third, compound task consisted of reproduction as the main task and target search as a secondary task. The response matrix was now a replica of the stimulus pattern exposed and the response instruction was the same as in the second task. After having completed the reproduction response, the subject was to mark the position of the target element. In the fourth and final search phase of the session, the subject's only task was to mark the target position on a replica of the stimulus pattern and to rate his confidence of a target hit on a scale of 0-10 categories.

The stimulus displays were exposed by means of a two-channel tachistoscope. First, a faint fixation cross appeared in the center of the visual field for 800 msec. Thereafter, immediately upon the offset of the fixation cross, a stimulus pattern was exposed. The luminance levels were: general illumination of the room = 31.4 mL, luminance of the field with the fixation cross = 15.1 mL, and luminance of the stimulus field = 15.1 mL. The exposure times were linked to task and individuals. For the reproduction tasks 1 and 2, the exposure times were set individually by means of the staircase method; stimulus pattern 55 with D=10 was used as test pattern until the subject consistently responded with "saw absolutely nothing" or "saw hardly any elements". The resulting exposure times for the subjects 1-3 were: 11, 15, and 13 msec, respectively. In the third, compound task with reproduction as the main task and target search as a secondary task, the exposure times were increased to 16, 19, and 17 msec (corresponding to "saw almost all elements"). In the final search task, the exposure time for all subjects was 250 msec.

Before each experimental session subjects were allowed 5 minutes for visual adaptation. In the first of the three experimental sessions they were extensively trained to fill in the response matrices according to the task requirements. A session started with a random subset of 20 stimulus patterns as a warm up. For each task, the 36 stimulus patterns were exposed in a random order. The time between trials was determined by the subject who initiated a push-button when prepared to respond. The subject was permitted to repeat the exposure once only in the case he did not perceive anything of the stimulus pattern exposed in task 1 and 2. Catch trials were used in the task of target search for one third of the trials.

Subjects

Three male professionals at the department in the ages 30-40 served as subjects. All subjects had normal vision.

Results

Judgmental classification of reproduced patterns. Two judges independently classified all reproductions made by the three subjects in the first and second task into five categories, defined with reference to the configurational properties of the stimulus patterns (S1 to S5). A sixth category contained complete misses. The judges agreed upon the classification for 97.5 percent of the 648 reproductions. A reclassification eliminated the disagreements. Data from the two tasks were pooled after inspection of the number of reproduced elements; the difference between the tasks reflected only a general performance increment for task 2 due to its lower task load. The results from the final classification are summarized in the S-R matrices of Table 1.

For the lowest density (D=5), few misses were noted for the systematic, redundant pattern S1(.04), the vertically grouped pattern S2(.04), and the random pattern S5(.03). In S1 and S5 there are easily detectable elements at the central retinal area which are missing at the conditions S2-S4. But the low rate of misses for S2 is compatible with the prediction of an elliptic and horisontally oriented functional field of

Table 1. S-R matrices resulting from the judgmental classification of reproduction data from the three subjects for the pooled data of the first and second task, and for density 5 and 10. (Entries are proportions with the decimal point omitted.)

DENSITY 5

		R-pattern					
		R1	R2	R3	R4	R5	MISSES
STIMULUS PATTERN	S1	39	05	02	04	46	04
	S2	07	33	00	02	54	04
	S3	04	00	20	02	55	19
	S4	02	00	04	24	57	13
	S5	26	00	00	02	69	03

DENSITY 10

		R-pattern					
		R1	R2	R3	R4	R5	MISSES
STIMULUS PATTERN	S1	96	00	00	00	04	00
	S2	00	91	04	02	03	00
	S3	02	00	87	11	00	00
	S4	00	00	11	87	02	00
	S5	50	01	01	04	43	01

view; at least some elements of the stimulus pattern will have a high probability of being detected due to their presence within the field. Accordingly, the stimulus pattern S3 is most frequently missed (.19) followed by S4 (.13) which also is empty of elements along the central horisontal axis. Furthermore, the fewer misses of S4, as compared to

S3, may be explained in terms of elements falling somewhat closer to the central retinal area in S4 (cf. Figure 1).

The inner borders, delimiting the empty field within the grouped stimulus patterns, are difficult to detect; the proportion of correctly identified S2-S4 patterns varied between .20-.33. There should be a difference in the ease of detecting the horisontal or the vertical borders of S2 or S3, as compared to detecting both the horisontal and the vertical borders of S4, since the latter decision should require more stimulus information. In fact, S4 is less easily identified than S2, but not than S3. However, the inequality between S2-S3 and S4 as regards central elements, allows no strict test of this hypothesis.

If the predicted shape and orientation of the functional field of view is correct, then the subjects should discriminate better between S2 and S4 than between S3 and S4. Actually, the reproductions of S3 and S4 are generally more similar than those of S2 and S4 according to the classification. Across densities the former are "confused" in 7 per cent of the cases, as compared to 1 per cent for the latter.

Increased density facilitates the identification of all stimulus patterns. No conclusions are possible as to the random configurations (S5), since they were inherently difficult to reproduce and the technique of reproducing them varied between tasks, densities, and subjects. R5 thus represents a miscellaneous category of unclassifiable reproductions.

Reproduced parts of the stimulus pattern. The number of elements reproduced in task 1 and 2 for each subject and stimulus configuration with D=5 were counted. The mean proportion of reproduced elements was calculated. (Data for D=10 were excluded from the analysis due to the strong ceiling effects.) Since there was no difference between task 1 and 2, except for the higher performance level in task 2, data for the two tasks were pooled. Figure 2 shows the mean proportion of reproduced elements with D=5 for each subject and stimulus configuration.

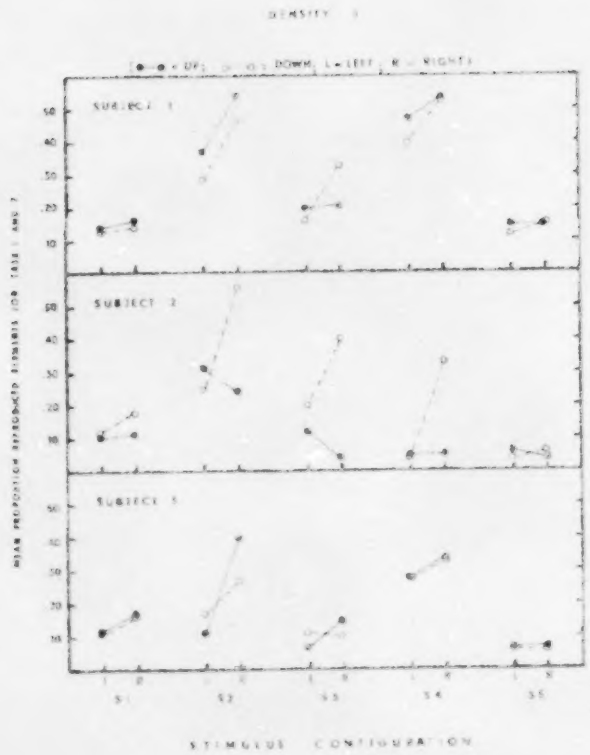

Figure 2. Mean proportion of reproduced elements for the pooled data of task 1 and 2 with D=5.

The general reproduction level is lower for S1 and S5 as compared to S2-S4. For the random configurations (S5) there are no asymmetries in the reproduced patterns for any of the subjects. The random nature of these configurations is reflected well in the reproductions. The systematic, redundant configuration S1 is apparently reproduced in a similar manner across subjects. This configuration contains no inherent directional properties, but there is a weak tendency to reproduce more of the right part of the pattern.

For the grouped stimulus patterns (S2-S4) with a lower spatial redundancy the configurational properties of the patterns evidently affect the reproductions. There are conspicuous asymmetries in the reproduced patterns for all subjects. Subject 1 and 3 have very similar patterns of reproduction, while the data for subject 2 reveals a different pattern. For subject 1 and 3 there is a clear tendency to give priority to the right parts of the stimulus configurations with S2 as the most obvious example. There also is a slight tendency to reproduce more elements in the upper-right quadrant of the S2-pattern. The differences between the up and down parts are small. For subject 2 a priority of the right part of the stimulus configurations S2-S4 can also be observed. But the most distinctive features for subject 2 is the down-effect and the priority of the lower right quadrant. The consistent reproduction strategy for subject 2 across S2-S4 was also reflected in the scoring of reproduced elements, with a very low rate of false alarms and a very high rate of misses. Thus, subject 2 used a very conservative response criterion and preferably reproduced the clearly perceived elements in the lower right part of the S2-S4 patterns. Subject 1 and 3 used a more lenient response criterion for S2-S4, although the false alarm rate still was low and the rate of misses fairly high.

In summary, there were no asymmetries in the reproductions across subjects for S5. They showed a weak right-tendency for S1 and a priority of the right part for S2-S4.

In the third, compound task there was a dramatic increase in the mean proportion of reproduced elements for all stimulus patterns (.88 for S2-S4 and .34 for S1 and S5 with D=5). For D=10 there was a clear ceiling effect (.96 across patterns). Thus, the configurational aspects of all the stimulus patterns were easy to perceive.

Target search. In the third, compound phase with reproduction as the main task and target search as a secondary task, the pattern of attended target positions might reflect the general configurational properties of the reproduced patterns. In the fourth, search phase, on the other hand,

the scanning patterns should become strongly contingent on the specific configurational properties of the stimulus displays. Figure 3 and 4 show the data from the search as a secondary and a primary task, respectively. Attended positions, as marked by the subjects,are plotted within the stimulus configuration. The plots also include responses on the catch trials. Encircled areas reflect clusters of responses significantly deviating from a rectangular distribution of expected positions. The fit was made by eye.

The overall dispersion of attended positions is evidently larger in the secondary task as compared to the primary task. Accordingly, there is a greater variability in scanning tendencies among the subjects. For the systematic configurations (S1-S4), a diagonal scanning tendency may be expected (Brännström, 1980); i.e. the upper left and the lower right parts of the stimulus pattern should be attended to. Subject 1 displays such a scanning tendency. The grouping of elements seems to put further restraints on the scanning of positions (see S2-S4); attended positions are concentrated to the inner contours. The diagonal scanning tendency for subject 1 probably explains the upper left priority for the random configurations (S5). For subject 2 a tendency to scan diagonally can be noted for S1, while a priority for the right part of the stimulus configurations holds for S2-S5. Inner contours seem less important for this subject than for subject 1. The pattern of attended positions for subjects 3 is very dissimilar over stimulus configurations, with inner contours being of small importance.

In the primary task (Figure 4), the attended positions are more strongly dependent on the specific systematic spatial configurations (S1-S4). For the random configurations (S5) they are still very dispersed. For subject 1 a diagonal scanning can be noted for S1, S2, and S4, while for S3 this tendency is modified by the two horisontal groupings of the elements. For S5 the scanning pattern is quite dispersed. Subject 2 reveals scanning patterns that are compatible with a diagonal scanning in S2-S4. S5 probably reflects a response bias also noted in the secondary task. Finally, for subject 3 a priority of the upper-left quadrant is evident for all configurations and modified only by the particular grouping of the elements in S3. Table 2 summarizes the results on attended parts of the stimulus patterns in the search tasks.

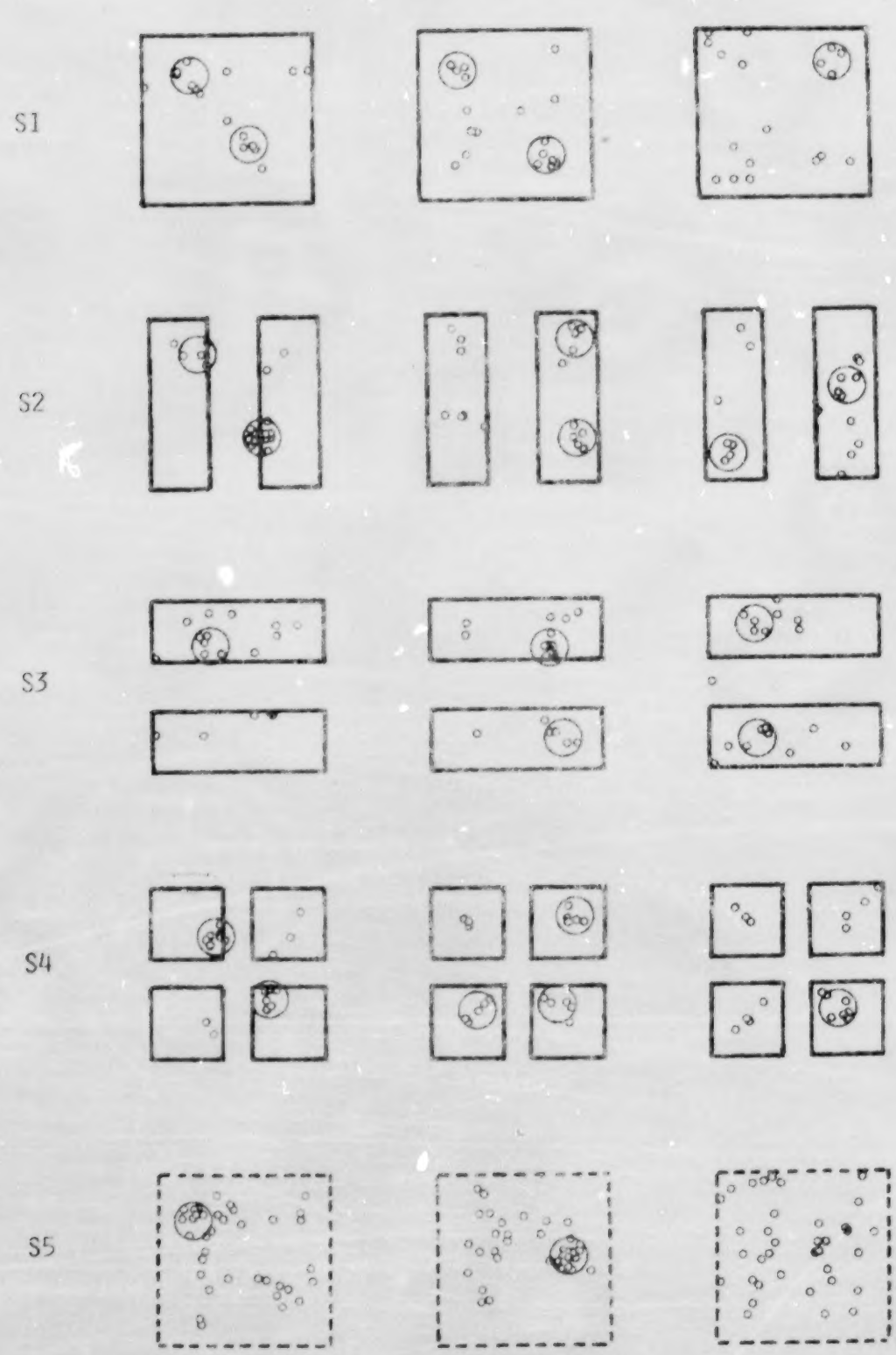

Figure 3. Attended positions in the target search (secondary task). Encircled areas mark clusters significantly deviating ($p < .02$) from a rectangular distribution of expected responses.

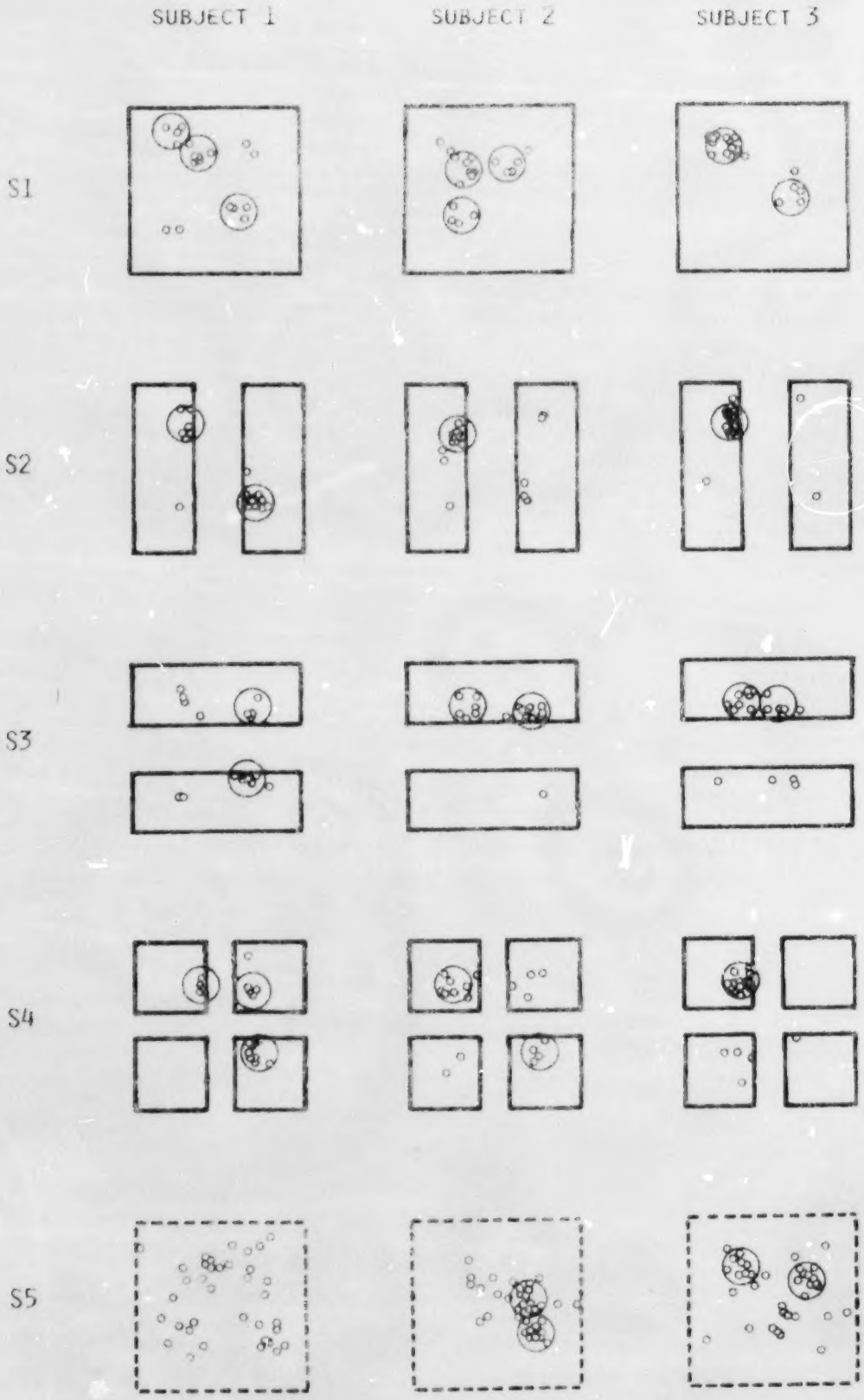

Figure 4. Attended positions in the target search (primary task). Encircled areas mark clusters significantly deviating ($p < .02$) from a rectangular distribution of expected responses.

A complementary study of the accuracy of target search was made by means of multiple regression analysis. The dependent variable was the distance between the target and the attended positions. One analysis per task, subject, and configuration was performed. The distance measure was used instead of a classification of correct and incorrect responses, since the subjects only occasionally hit the exact target position. The regression equation contained the following factors (cf. Brännström, 1980): LR - left/right part of the stimulus pattern, UD - up/down part, LRxUD - an interaction term formed by the products of the former factors and A - the distance between the fixation point and the target position (i.e. angular distance). The factors were entered in the regression equation in the order LR, UD, LRxUD, and A. Table 2 contains the outcome of the multiple regression analyses. Statistical significancies refer to the regression analyses.

Comparing the secondary with the primary task confirms the data on the scanning patterns (cf. Figure 3 vs. 4): (a) The greater overall dispersion of attended positions in the secondary task is reflected in less pronounced effects of the spatial factors used in the regression equation. (b) The interindividual differences are larger in the secondary task as regards the scanning tendencies of the subjects. Thus, by making the search task primary a smaller number of applicable scanning strategies is induced. Scanning tendencies still differ among the subjects, but to a much smaller extent than in the secondary task. For the random configurations (S5), a clear effect of angular distance (A) of the target element should be observed. The effect reaches significance for subjects 1 and 2 in the secondary task ($p < .10$ and $p < .05$, respectively), and for all subjects in the primary task (.10, .01 and .01, respectively).

There are some differences between the attended position data and the regression data that should be noted. First, some expected significant effects of the spatial factors in the secondary task are missing which reflects the fact that each regression analysis for S1-S4 was based on only 12 observations and that there was a large dispersion of the attended positions. The small sample of observations also causes the opposite effect: an occasional target hit will contribute heavily to the significance of a spatial factor.

Table 2. Spatial effects in the primary and the secondary search task. (a) Summary description of the distribution of attended positions. (b) Significant spatial factors in the MR-analyses (see text for explanation).

SECONDARY TASK

	SPATIAL CONFIGURATION				
	S1	S2	S3	S4	S5
SUBJECT 1	DIAGONAL(a) -	DIAGONAL RD**(b)	DIAGONAL & UP -	DIAGONAL -	NONE LU** A*
SUBJECT 2	DIAGONAL -	RIGHT R**	RIGHT R***	UP U**	NONE LU*** A**
SUBJECT 3	NONE -	DOWN -	LEFT L**	LEFT -	NONE -

PRIMARY TASK

SUBJECT 1	DIAGONAL U**	DIAGONAL R** RD**	RIGHT -	DIAGONAL U*	NONE A*
SUBJECT 2	LEFT UP U***	DIAGONAL RD**	UP U*** R** LU*	DIAGONAL --	RIGHT DOWN A*** RD**
SUBJECT 3	DIAGONAL & LEFT UP U***	LEFT UP L** U**	UP U**	LEFT UP -	NONE A*** R*

Note: Significant effects of the spatial factors need not be compatible with the attended position data, since the data used for the multiple regression analysis did not include catch trial data. (*p < .10; **p < .05; ***p < .01.)

Discussion

The present experiment confirms the significance of spatial factors on both an initial segmentation phase and a following attentional phase in visual information processing. Are the two phases differentially affected by the spatial factors which were manipulated in the experiment? The answer seems to be yes.

There are considerable differences between the reproduction data and the search data (Figure 2 vs. 3-4 and Table 2). The priority of the right part of the stimulus field for the systematic stimulus configurations S1-S4 in the reproduction data is not replicated in the search data. An exception is subject 2, with a priority of the right part of the stimulus field in both reproduction and search (secondary task). Even for this subject, however, the correlation disappears when search is the primary task. For the random configurations (S5) there are no obvious differences between reproduction and search. The element positions are attended according to their distance to the fixation point. This effect of the retinal position is absent for the systematic configurations. Thus, the difference between the data from reproduction and that of search may suggest that the configurational aspects extracted during the initial, segmentation phase are independent of the scanning strategies in the attentional phase.

The results from the judgmental classification of the reproduced parts of the stimulus patterns in task 1 and 2 (see Table 1) are compatible with the proposed properties of the segmentation phase. The ease of detection and identification of the stimulus patterns is affected by the retinal position of the elements; their spatial redundancy; the density, form, and orientation of the functional field of view. The rate of "confusions" between patterns lends further support as to the impact of these factors. On the other hand, the attentional phase utilizes more specific properties of the stimulus configuration due to the particular task requirements. When the search task is primary, as compared to secondary, the overall dispersion of the attended positions will be smaller both intraindividually and interindividually. The strong tendency to attend the upper left and the lower right parts for the systematic configurations, replicates the findings of Brännström (1980).

How sensitive are the methods to reveal aspects of the initial, segmentation phase and the attentional phase? The reproduction method used to measure the perceived gross features of the stimulus configurations is evidently able to capture the salient aspects of the stimulus pattern, as is shown by the judgmental classification. In the primary search task, the subjects repeatedly reported a very clear perception of the target element and made a correspondingly high confidence rating. In general these attended positions represented false alarms which tended to cluster in a few restricted parts of the stimulus display. This phenomenon seemed to happen almost obligatory since it was contrary to the subject's expectations of an even distribution of the target locations. The explanation is that some incompletely processed stimulus element, o, in the attended part of the configuration will be recognized as the target element, c.

To summarize, the spatial factors seem to have differential effects on the initial segmentation phase and the following attentional phase as reflected by the reproduction and the search data, thus, supporting a hypothesis of relatively independent phases. The immediate perception of the gross features of the stimulus patterns are very well captured by the reproduction method.while the search data suggest that some specific properties of the stimulus configurations may not be utilized until rather late in the processing. In the same vein there were no indications of interferences from the scanning strategies into the segmentation phase, since no substantial correlations between the attended positions and the reproductions was observed.

This investigation was supported by a grant from the Swedish Council for Social Science Research.

References

Brännström L. Effects of spatial configuration on search of visual displays. Umeå Psychological Reports, No. 151, 1980.

Estes, W. K. Perceptual processing in letter recognition and reading. In Carterette, E. C., & Friedman, M. P. (Eds.). Handbook of perception. Volume IX. New York: Academic Press, 1978. Pp 163-220.

Haber, R. N., & Hershenson, M. The psychology of visual perception. New York: Holt, Rinehart & Winston, 1973.

Schaller, M. J., & Dziadosz, G. M. Individual differences in adult foveal visual asymmetries. Journal of Experimental Psychology: Human Perception and Performance, 1975, 1, 353-365.